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ABSTRACT

Two questions about the effects of microcomputer-based laboratory (MBL) activities on graphing skills were addressed in this study: (1) the extent to which activities help students link their concrete experiences with motion with graphic representations of these experiences; and (2) the degree of importance of the real-time aspect of the MBL in contributing to this understanding. The subjects were 93 high school physics students who were assigned to one of four treatments: (1) a standard MBL activity; (2) an MBL activity with the graph display delayed 20 seconds; (3) a pencil and paper graph construction activity; and (4) no activity. Posttest scores for the standard MBL treatment were significantly higher than scores from all other treatments on distance-time graphs, but not on velocity-time graphs. Scores of the delayed-MBL group were not significantly different from either of the two control treatments. These results provide indicators of the way in which children make the cognitive translation between concrete and symbolic representations of an event. Eight references are listed. (Author/MES)

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THE ROLE OF MICROCOMPUTER-BASED LABORATORIES IN LEARNING TO MAKE GRAPHS OF DISTANCE AND VELOCITY

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Paper to be presented to the annual meeting of the American Education Research Association at Washington, DC, April, 1987.

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Abstract

The objective of this study was to explore the effects of microcomputer-based laboratory (MBL) activities on graphing skills under carefully controlled pedagogical conditions. Two questions were addressed: 1) To what extent does MBL help students link their concrete experiences with motion with graphic representations of these experiences; and 2) Of what importance is the "real-time" aspect of MBL in contributing to this understanding?

After only one class session, high school students using MBL scored significantly higher than control groups on questions involving distance-time graphs, but not velBcity-time graphs. Most of the improvement was attributable to the real-time graphing feature of MBL. The results provide interesting indicators of the way in which children make the cognitive translation between concrete and symbolic representations of a given event.

Introduction

Developers, teachers, and researchers have found that experience with microcomputer-based laboratory (MBL) activities is effective in improving students' understanding of graphs of physical events for middle-school students (Linn et al., in press; Mokros & Tinker, 1987) and for college students (Thornton, 1986). Such improvement may be particularly beneficial in kinematics, where students have difficulty both with the concepts and with the graphs as a medium of representation (Halloun & Hestenes, 1985).

This research examines the initial impact of MBL in facilitating high-school physics students in understanding how distance and velocity information is represented in graphs. Two general questions were addressed: 1) To what extent does a very brief experience with a kinematics MBL help students to cognitively link a physical event with a graphic representation of it, and 2) What feature(s) of the MBL are responsible for any improvement?
As a learning environment, MBL activities provide students with more time for experimentation and more opportunity for interpreting rather than collecting data. As a tool, MBL provides high quality data in real time. Displaying the data as graphs on the computer screen at the same time the data are generated by a physical event (real-time display) has two important components--the

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feedback is immediate and visually dynamic. Any or all of these features may have a considerable impact on information processing and/or motivation. This study focusses on a single feature, the immediacy of the real-time graph display. By delaying the presentation of the graph until after the data have been collected (approximately 20 seconds) and then displaying the data at the same rate as they were collected, the immediacy of display can be separated from all other attributes of the activity.

Methods

Students in entire Physics classes (7-17 students in each class) from seven rural schools in north Florida participated in the experiment--a total of 93 students. Students were mostly seniors with an average age of 17.7 years. All students had already been taught a unit on kinematics earlier in the academic year so the experimental activities, dealing with distance and velocity, were a review of familiar concepts.

The experiment extended over three days for each class, one day each for pretests and orientation, treatment, and posttests and debriefing. Tests included a test of verbal ability, and content-specific, multiple-choice pretest and posttest. Details of the experimental design and treatments are available in Brasell (1987).

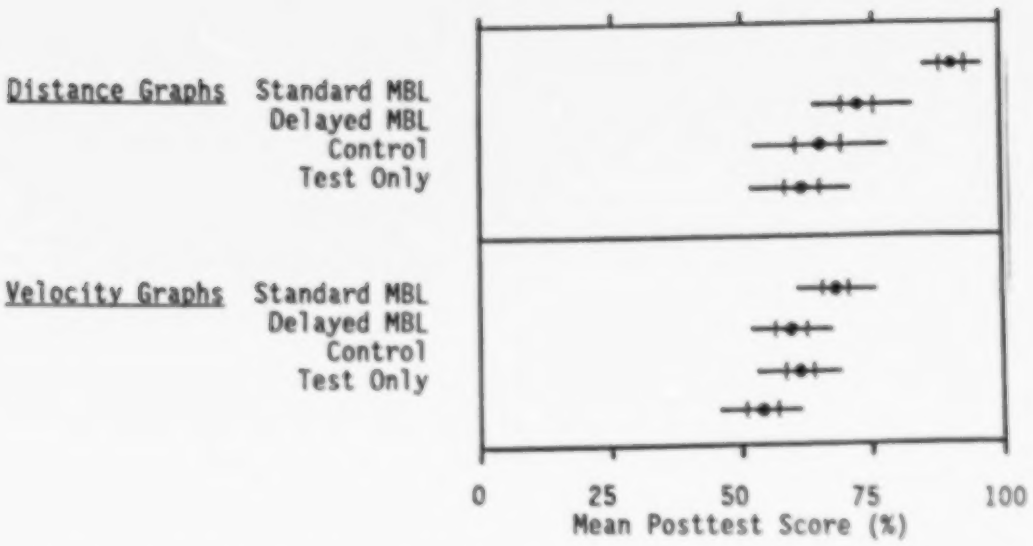
In each class, students were assigned to one of four treatments.

1) Standard MBL--a MBL activity using the motion detector and worksheet. Software was altered to eliminate options that were unnecessary to the experiment.
2) Delayed MBL--the same as Standard MBL except that the graph display was delayed approximately 20 seconds.
3) Pencil and paper--a graph-construction control activity where students worked with the same graphs and concepts.
4) Test Only--a statistical-control with no activity.

Students worked individually for all tests, but in groups of 2-3 students for the treatment activity.

Results

Nearly all of the improvement of MBL students on the posttest was accounted for by the immediacy of the graph display (difference between Standard-MBL and Delayed-MBL treatments). Factorial analysis of covariance controlled for ability and score on the pretest. Results indicated that posttest scores from the Standard-MBL treatment were significantly higher ($p<.001$) than scores from all other treatments. When scores for distance items were analysed separately from those for velocity, scores for the Standard-MBL students were significantly higher only for distance items. The difference for velocity items was not significant ($p=.156$). Scores of the Delayed-MBL students were not significantly different from scores from either of the two control treatments.



Posttest scores: mean, 50%, and 95% confidence limits.

Discussion

The appearance of these differences after such a very brief treatment, one class period, suggests that there is a fundamental difference in information processing generated by the immediate display. Why was the immediacy of display so effective in developing a cognitive link between a concrete event and the graphic representation of the event? The delay was not long enough to have caused a serious difference between treatments in the opportunity for practice, repetition, or interpretation of results. There are several possible explanations, which are not necessarily either distinct or incompatible.

One possibility is that real-time graphing allows learners to process information about the event and the graph simultaneously rather than sequentially (i.e., parallel rather than serial information processing). Rapid cognitive linking in short-term memory may occur and this would increase the likelihood of the linked information being transferred to longterm memory as a single unit. The linking in time of a physical event with a simultaneous graphic representation may thus facilitate an equivalent linking in memory (Mokros & Tinker, 1987).

For students in the Delayed-MBL treatment to make an effective cognitive linkage between an event and a graph, they would have to transfer information about the event to long-term memory or maintain it in short-term memory until the graph was displayed. Short-term or working memory is limited in capacity, retention time, and rate of transfer to long-term memory (Bransford, 1979). Novices in a particular task are unsure to what features they should attend and are susceptible to cognitive overload. Real-time display may function as a "memory support" system (Marcia Linn, personal communication) by reducing the demands on memory between the occurrence of the event and the display of the information. In this study, there was no such evidence that the additional memory load exceeded the students' limited cognitive capacity.

If there is no cognitive overload, the maintenance and rehearsal techniques necessary to bridge the delay should improve, not inhibit, learning and retention of information (Bransford, 1979). However, students in the Delayed-MBL treatment did not attempt to use appropriate maintenance and rehearsal techniques during the delay. They just waited passively. They did not appear to have appropriate learning strategies. They did not even know how to observe. In contrast, the immediate display seemed to cue the students to specific features of the graph and event (e.g., change of slope, change of direction), helping them to isolate and attend to only relevant information.

Finally, the additional cognitive burden may have required more effort than students were prepared to expend or the immediate display may have been more intrinsically motivating. Immediate display appeared to make the graphs responsive and controllable, making the abstract and theoretical properties of the system behave as though they were concrete. Mokros (1986) suggests that this may operate as a bridge to formal reasoning and development. Observations during the experiment revealed that students in the Standard-MBL treatment displayed a greater sense of autonomy, initiative, curiosity, and purpose. All of these are indicators of positive motivation (Lepper, 1985) and may result from a greater sense of competence generated in the Standard-MBL treatment.

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